AD-A039 463 AIR FORCE ROCKET PROPULSION LAB EDWARDS AFB CALIF F/G 21/8.2

PULSED BATES TESTING.(U)

APR 77 J E HEWES, J J DONN

UNCLASSIFIED AFRPL-TR-77-16 NL

| OF |

AD
A039463

END

DATE
FILMED
6-77

AFRPL/TR-77-16

12

NW

PULSED BATES TESTING

FINAL REPORT

JACK E. HEWES, PROJECT MANAGER
JACK J. DONN, CAPT., USAF
AIR FORCE ROCKET PROPULSION LABORATORY
EDWARDS AFB, CA 93523

APRIL 1977

Approved for Public Release

Distribution Unlimited

AIR FORCE ROCKET PROPULSION LABORATORY
DIRECTOR OF SCIENCE AND TECHNOLOGY
AIR FORCE SYSTEMS COMMAND
EDWARDS AFB, CALIFORNIA 93523

NOTICES

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

FOREWORD

This is the final report on the Pulsed Bates Testing program conducted in-house by the Combustion Technology Section, Air Force Rocket Propulsion Laboratory. The program was conducted under Project Number: 573010CS. This report covers the testing done on the BATES motor system to assess the feasibility of pulsing to obtain combustion response data on a full scale motor system. The report covers the testing between March 75 and Sep 75 and the subsequent data analysis. Project Manager for the program was Mr. Jack E. Hewes. Instrumentation assistance was provided by Mr. Richard Grove (AFRPL/TEBC).

This report has been reviewed by the Information Office/DOZ and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations. This technical report has been reviewed and is approved for publication; it is unclassified and suitable for general public release.

Jack E. Hewes

JACK E. HEWES, GS-13
Project Manager

Wilbur C. Andrepont

WILBUR C. ANDREPONT
Chief, Combustion Section

William F. Morris

WILLIAM F. MORRIS, Colonel, USAF
Chief, Technology Division

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: (14) AFRPL-TR-77-16
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): (6) PULSED BATES TESTING
5. TYPE OF REPORT & PERIOD COVERED: (9) Final Report, ~~3/75-7/75~~
6. PERFORMING ORG. REPORT NUMBER: Mar-Jul 75
7. AUTHOR(s): (10) JACK E. HEWES, PROJECT MANAGER; JACK J. DONN, Capt, USAF
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AIR FORCE ROCKET PROPULSION LAB (DYSC), EDWARDS AFB, CA 93523
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (16) 573010CS (17) 10
11. CONTROLLING OFFICE NAME AND ADDRESS
12. REPORT DATE: (11) April 1977
13. NUMBER OF PAGES: 15
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 20p.
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report): Approved for Public Release: Distribution unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): Approved for Public Release: Distribution unlimited
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Pulsing Motors, Pulsers, combustion instability

ACCESSION for		
NTIS	White Section	☒
DDC	Buff Section	☐
UNANNOUNCED		☐
JUSTIFICATION........		
BY........		
DISTRIBUTION/AVAILABILITY CODES		
Dist.	AVAIL. and/or SPECIAL	
A		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This experimental program was conducted to study the feasibility of pulsing a BATES motor and obtain combustion response data without interfering with motor performance measurements. The report details the testing performed using both piston and powder pulsers and the resulting data. It was concluded that such testing is feasible and follow-on developments are planned.

DD FORM 1473, 1 JAN 73 — EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

307720

1B

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

1.1 As early as 1963, pulse techniques were employed[1] for establishing stable operating regimes in solid propellant rocket motors. The utility of the method was, however, limited to instances where the motor was unstable to a finite amplitude excitation. The successful application of pulsing techniques to the quantitative study of linear (or incipient) stability of aluminized propellants in the T-Burner[2] suggested the possibility that similar techniques could be employed on full scale development motors to (1) establish the degree of incipient stability of the motor and (2) determine if the motor is sensitive to pulse excitation. The first objective would allow an assessment of the relative combustion stability characteristics of several motor-propellant systems and at the same time provide data for evaluating the validity of stability prediction models. The second objective would provide a means of minimizing the risk of instability initiated by the unexpected ejection of material through the nozzle throat.

1.2 With the above goals in mind, AFRPL began a series of motor tests to evaluate the adaption of the T-Burner pulsing technology to full scale motor pulsing. A decision was made to study and test the feasibility of pulsing a standard ballistic test motor to obtain combustion response data. If feasible, this would allow the obtaining of both performance and response function data on a single test and provide combustion response data earlier in a propellant's development than other methods now in use. The Ballistic Test and Evaluation System (BATES) was chosen for testing.

---

(1) Morris, E. P., "A Pulse Technique for the Evaluation of Combustion Instability in Solid Rocket Motors," Canadian Aero, and Space Journal, <u>11</u> (9), 1965.

(2) Culick, F. E. C., "T-Burner Testing of Metallized Solid Propellants," AFRPL-TR-74-28, Oct 1974.

2. TEST EQUIPMENT

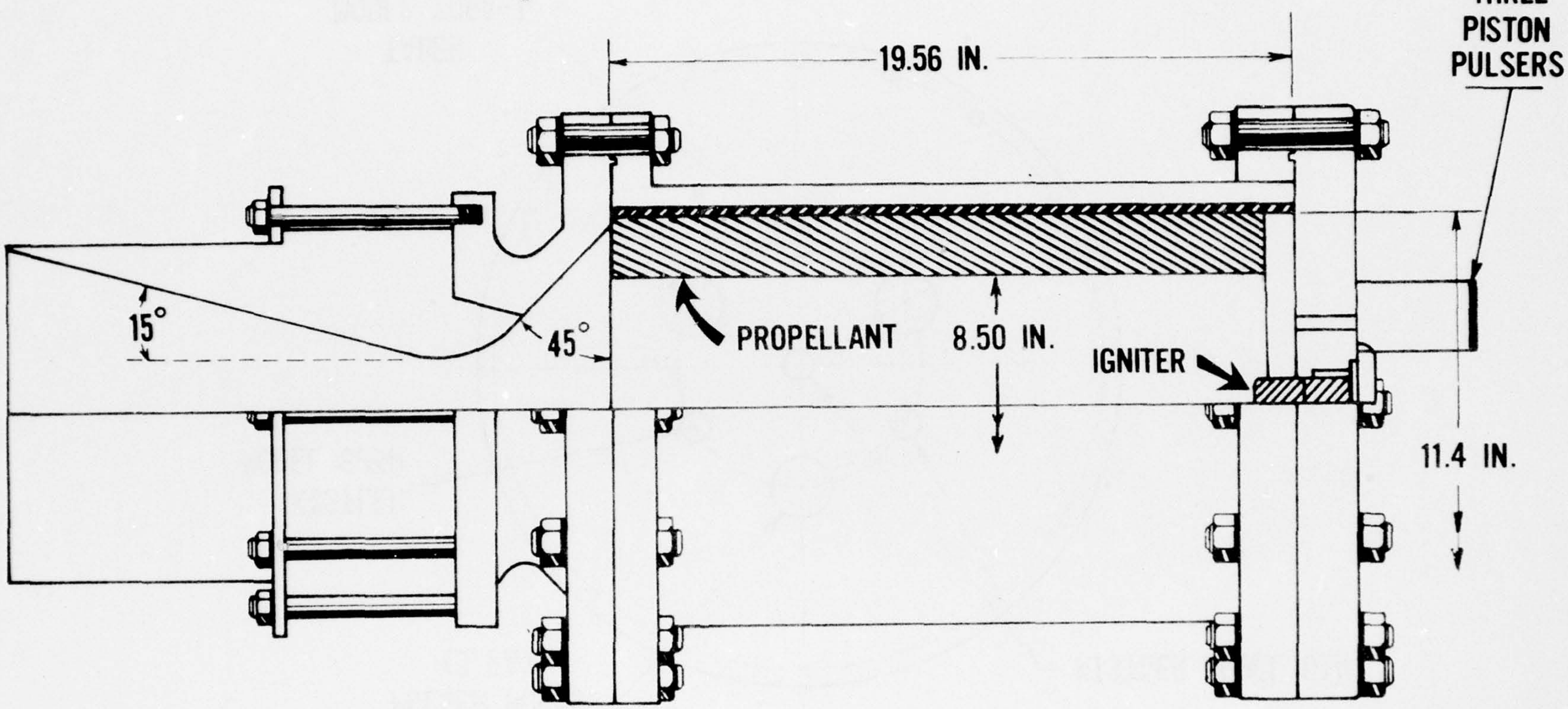
2.1 A standard seventy pound BATES motor (Fig. 1) was modified for this series of tests. To accommodate the instrumentation and pulsing hardware, the headplate (Fig. 2) was modified by adding the required porting for mounting these items. As shown there are three pulser vent ports and porting for four pressure transducers in the headplate. The igniter port, usually in the center of the headplate, was eliminated to provide space for the modification. As a result of this modification the motor was ignited by use of a bag igniter inserted through the throat of the motor. Due to the interferences of the head mounted pulsers, the normal test stand mounting could not be accomplished. An adapter was made (Fig 3) to install the modified motor to the thrust mount and still permit installation of the pulsers without removing any hardware. The adapter is a section of twelve inch diameter stainless steel pipe twenty four inches long and flanged at both ends to permit mounting. Three cutouts in the adapter, spaced at 120° apart, permit access to the motor headplate.

2.2 The thrust stand used for these tests was an Ormond three point system and is located at the AFRPL, Test Area 1-52, Pad B.

2.3 The first of the two pulsing devices tested was the piston pulser (Fig. 4). The piston pulser is a three chambered arrangement. The initial chamber holds the driving charge of shotgun powder and has a burst disk of brass shim stock separating it from the second chamber. The second chamber is analogous to the automotive combustion chamber in that the hot expanding gases, after rupturing the burst disk, drive the piston towards the motor. The third chamber is open to the motor and filled with motor combustion gases during motor operation. As the piston moves under the impetus of the driving charge, the gases in this chamber are injected into the motor combustion chamber causing a perturbation in the chamber pressure. The

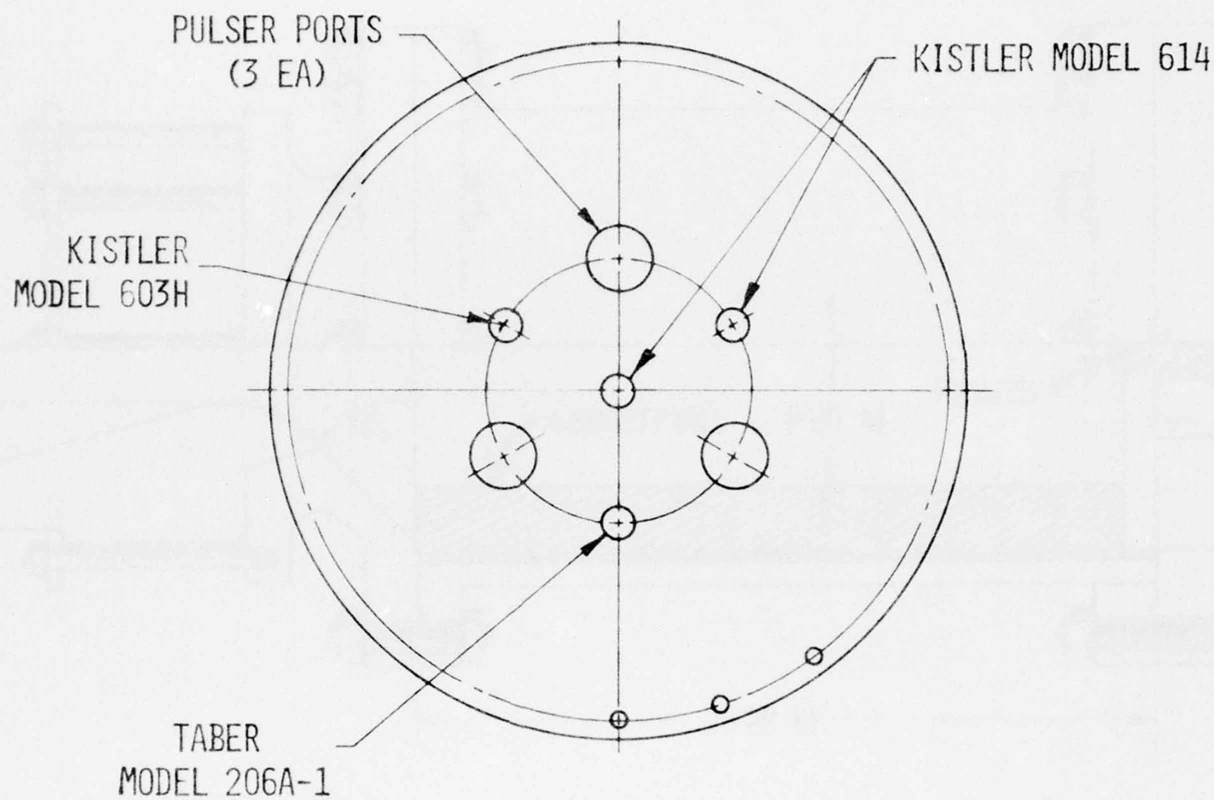
CURRENT PURPOSE OF BATES MOTOR:

TO MEASURE I_{sp} & C* OF SOLID PROPELLANTS



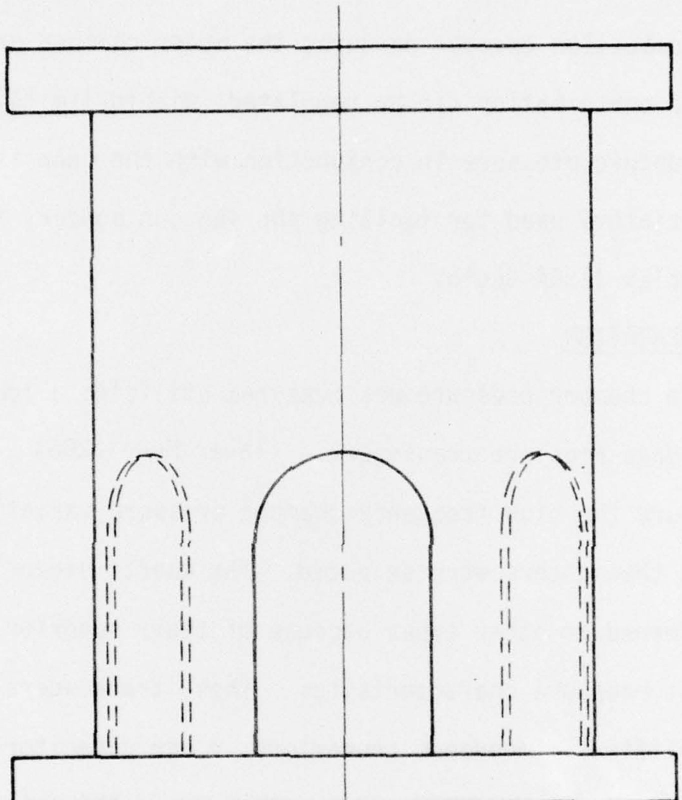
70 LB BATES MOTOR

FIG. 1



HEAD CLOSURE(MODIFIED)

FIG. 2



MOTOR ADAPTER
FIG. 3

amplitude of this perturbation can be regulated, within limits, by two means, individually or in combination. One way is to vary the driving charge and the other is to vary the piston stroke by adding or removing the teflon washers at the motor end of the piston stroke.

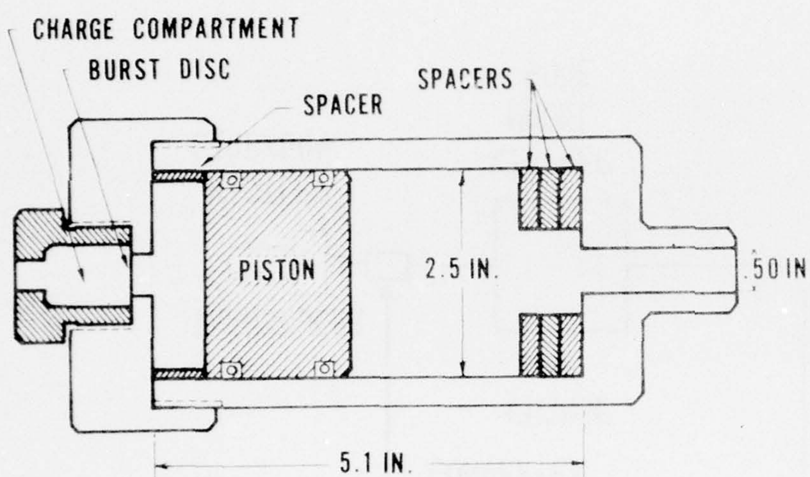
2.4 The second of the pulsing methods tested was a powder pulser (Fig. 4). This is a single chambered device which utilizes a charge of shotgun powder to create the pressure which ruptures a burst disk. The resultant release of gas into the motor combustion chamber perturbs the motor chamber pressure. The amplitude of this perturbation can be regulated, within limits, by controlling the burst disk rupture pressure in conjunction with the quantity of powder.

2.5 The initiators used for igniting the shotgun powder, in both type pulsers, was a Holex 1196A Squib.

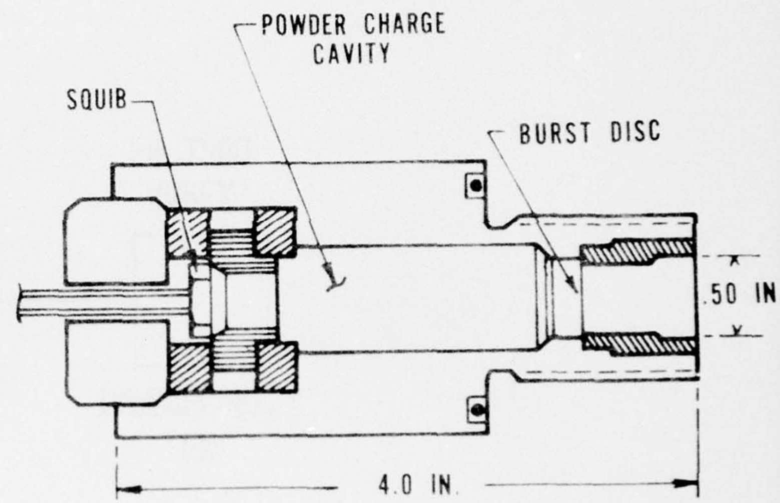
3. INSTRUMENTATION

3.1 The mean chamber pressure was measured utilizing a low frequency response strain gage pressure transducer. (Taber Model-206)

3.2 To measure the high frequency chamber pressure variations, Kistler dynamic pressure transducers were selected. The quartz piezoelectric transducers were preferred to other types because of their superior ability to measure transient pressure characteristics. These transducers were used with gated charge amplifiers, impedence converters, range capacitors and low noise cables to reduce high frequency distortion (Fig 5). The gated charge amplifiers were timed to record the high frequency, low magnitude pressure variations modulating the chamber pressure during the pulsed mode. The pressure instrumentation circuit was grounded during ignition and activated about 0.3 seconds after ignition. The circuit was again grounded 0.7 seconds before burnout. This method was used to avoid amplifier saturation during the large pressure transitions of ignition and burnout. Consequently, the

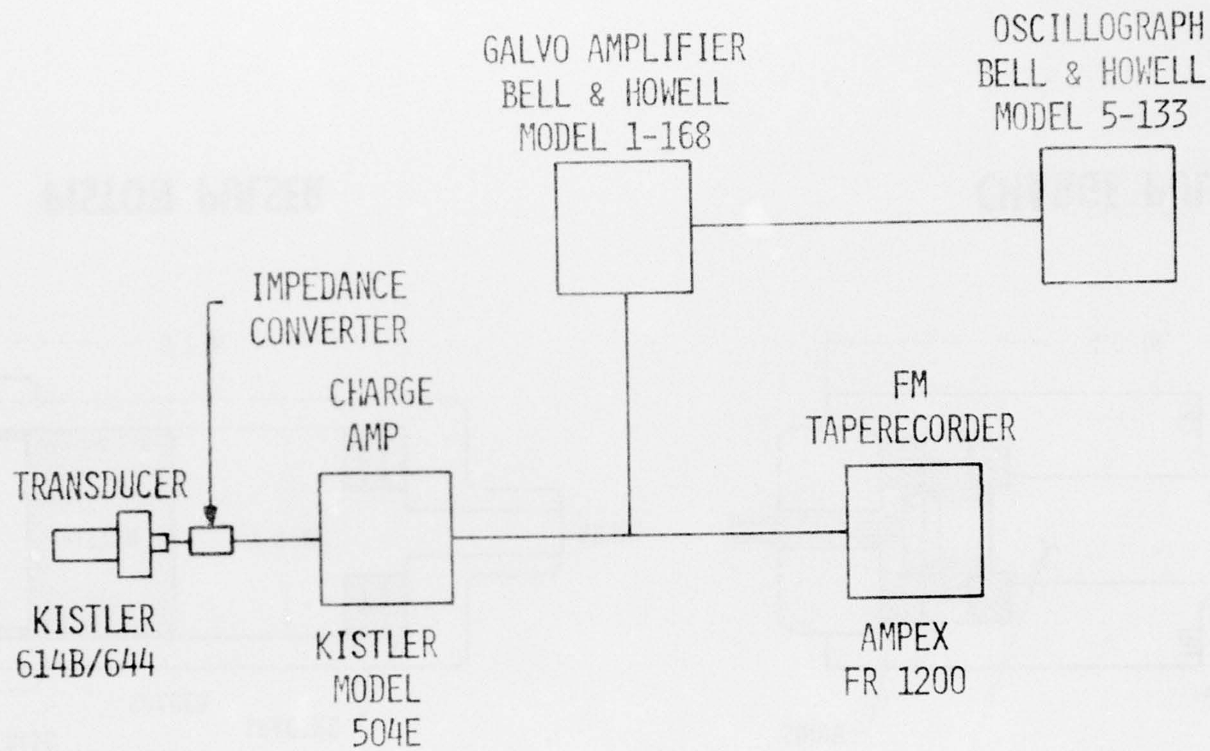


PISTON PULSER



CHARGE PULSER

FIG. 4



TYPICAL INSTRUMENTATION SYSTEM

FIG. 5

large pressure excursions at motor start and shutdown were not recorded on the high frequency system. There were no electronic filters used in this system between the transducer and recording system.

3.3 The typical components used in the high frequency data acquisition system are as follows.

MANUFACTURER	COMPONENT	MODEL
Kistler	Pressure Transducer	603H/623F
Kistler	Pressure Transducer	614A2/644
Kistler	Pressure Transducer	614B/644
Kistler	Charge Amplifier	504E
Kistler	Calibrator	536A
Kistler	Impedance Converter	556A
Kistler	Insulation Tester	537A
Kistler	Range Capacitor	5-571A2
Ampex	Tape Recorder	FR1200
Eagle Signal	Electronic Timer	HM100

The impedance converter used a MOS FET IC circuit, operating as a source follower, to create a high-to-low impedance transformation and charge-to-voltage conversion before the pressure data entered the 1200 foot cable going to the recording equipment in the control station. Where possible, off-ground conditions were maintained to eliminate ground loop problems, which were experienced with grounded transducers. All high impedance transducer components were secured mechanically to minimize spurious charge generation caused by component vibration. In the control station, an electronic timer controlled gated charge amplifiers which were used to provide power to the impedance converters.

3.4 The data were recorded on Ampex FR-1200 tape recorders operating at 60 ips in the I-band FM mode with a flat frequency response of DC to 10,000 H_z.

3.5 The two model 614 Kistler transducers used were of the water cooled, (150 psig, ambient water) helium bleed (1000 psig helium) type. These were used to avoid the temperature effects of hot gases from the motor causing a drift in transducer output. The use of the model 614 in this application is not common practice; however, it did show better thermal stability than the uncooled model 603H.

3.6 In addition to the pressure transducers, there were four accelerometers attached to the exterior of the motor case (Fig.6). The accelerometers used were Kulite model 2264A which are piezoresistive quartz crystal units with sensitive axis oriented in the radial direction.

4. TEST PROGRAM

4.1 A total of twenty one tests were made during this program.

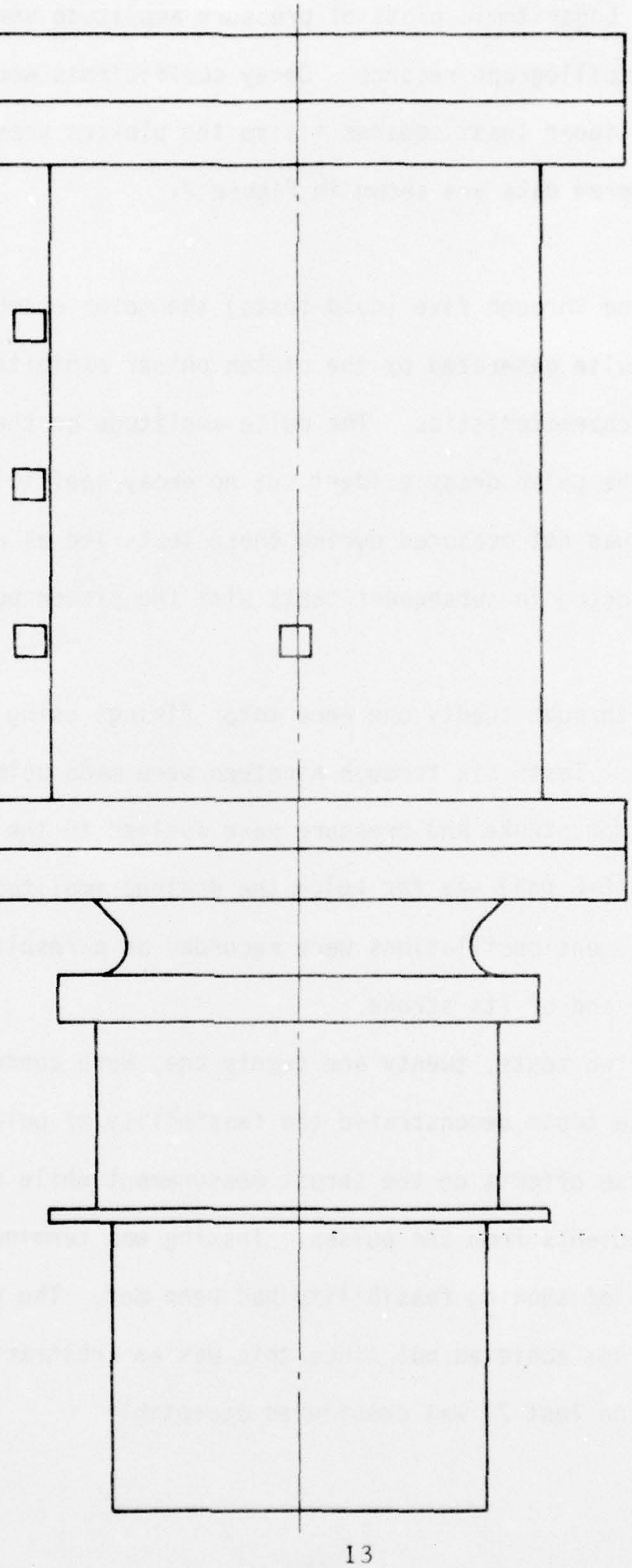
4.2 The initial five tests were cold tests using a blanked off motor case without propellant. The case was pressurized with GN_2 to nominal chamber pressure and pulsed three times. These tests were performed to check out the instrumentation and control systems and size the required pulser characteristics.

4.3 The remaining sixteen tests were made using an aluminized propellant. The motors were pulsed three times during each test with the pulsers timed to fire at 1/4 burn, 1/2 burn and 3/4 burn. The propellant used was 73% AP, 14% aluminum, 13% R-45-HTPB, and had a burn rate of 0.39 in/sec at 1000 psi.

4.4 The target pulse amplitude for these tests was 20 psi (0 to peak).

5. DATA REDUCTION

5.1 Reduction and analysis of the pulse data employed procedures similar to those recommended for reduction of T-Burner pressure data[2]. The FM tape was replayed at reduced speed (7.5 ips) through a Kronhite band pass filter



ACCELEROMETER LOCATIONS

FIG. 6

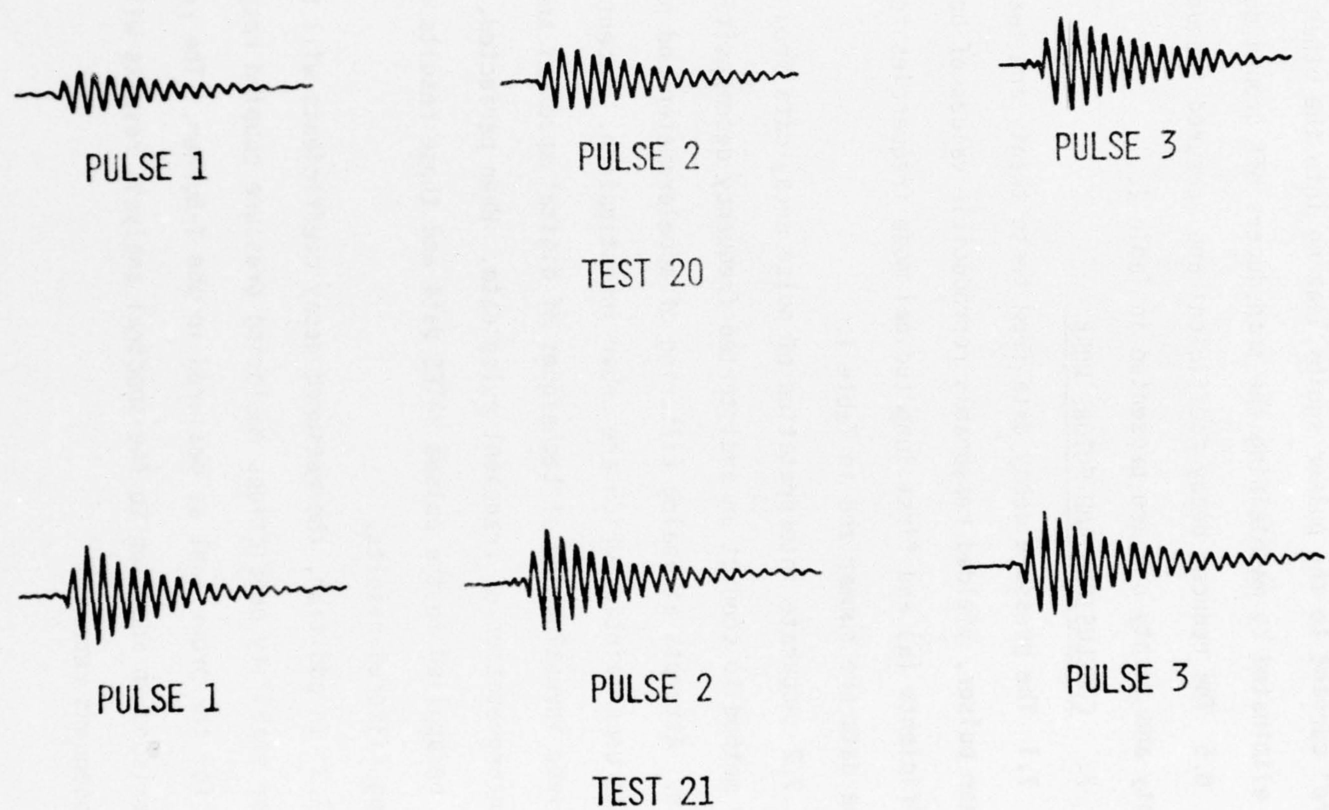
with center frequency corresponding to the first longitudinal mode of the motor and a 100 Hz bandwidth. The filtered signal was recorded on a high speed oscillograph. Logarithmic plots of pressure amplitude versus time were made from the oscillograph records. Decay coefficients were obtained from the slope of a linear least squares fit to the plotted pressure data. Examples of the filtered data are shown in Figure 7.

6. RESULTS

6.1 In tests one through five (cold tests) the motor chamber reactions resulting from the pulse generated by the piston pulser exhibited pulse amplitude and decay characteristics. The pulse amplitude on these was about 15 psi average and the pulse decay evident but no decay coefficients were calculated. Thrust was not measured during these tests and as a result the thrust oscillations noted in subsequent tests with the piston pulser were not in evidence.

6.2 Tests six through twenty one were motor firings using the propellant noted in Section 4.3. Tests six through nineteen were made using piston pulsers. Even though the maximum stroke and pressure were applied to the piston pulser, the pulse amplitude (6-8 psi) was far below the desired amplitude of 20 psi. Severe thrust measurement oscillations were recorded as a result of the piston bottoming out at the end of its stroke.

6.3 The final two tests, twenty and twenty one, were conducted with the powder pulser. These tests demonstrated the feasibility of pulsing the motor system without adverse effects on the thrust measurement while obtaining measurable decay coefficients from the pulses. Testing was terminated at this point since the goal of showing feasibility had been met. The goal of a 20 psi pulse amplitude was not achieved, but since this was an arbitrarily set goal, the 12 psi obtained on Test 21 was considered acceptable.



PULSE DECAY DATA

FIG. 7

6.4 During the tests, electrical noise in the pressure transducer circuits proved to be a problem. The major source of this noise was found to be the "fire" current to the pulser squibs leaking into the other circuits. The problem was eliminated by maintaining the transducers off ground during squib firing.

6.5 The reduced decay coefficient and measured frequencies for tests twenty and twenty one are presented in Table I.

7. CONCLUSIONS AND FUTURE WORK

7.1 The pressure decay data from tests twenty and twenty one, using the powder pulser, yielded reasonably reproducible values of both linear decay coefficients (α) and first longitudinal mode frequencies for the three pulses. These data are summarized in Table I.

7.2 Accurate interpretation of pulse decay data from motors requires some method to conduct an undistorted frequency decomposition of the decaying pulse. Attempts at analog filtering of accelerometer and pressure data has led to uncertainties which are under investigation. Recent work at AFRPL has involved investigation of techniques of digital spectral analysis as applied to interpretation of transient pulse data. When perfected, these techniques will be applied to the pulsed BATES data and those results compared to the analog filtered results.

7.3 In addition, the measured decay coefficients will be compared to linear stability predictions employing pressure coupled response function data for the propellant as measured in the T-Burner. The results of these comparisons in addition to the spectral analysis results will be published in a subsequent report.

RUN 20	PULSE 1	PULSE 2	PULSE 3
AMPLITUDE (PSI)	3.9	6.1	8.7
FREQUENCY (Hz)	919	930	987
α (SEC^{-1})	-114.9	-130.5	-136.6
POWDER CHRG (gms)	1	1 1/2	2
BURST DISK (in.)	.006	.006	.006

RUN 21	PULSE 1	PULSE 2	PULSE 3
AMPLITUDE (PSI)	12	12	12.5
FREQUENCY (Hz)	919	930	975
α (SEC^{-1})	-107.8	-132.8	-127.8
POWDER CHRG (gms)	1 1/2	1 3/4	2
BURST DISK (IN.)	.008	.008	.008

TEST DATA FOR RUNS 20 AND 21

TABLE I